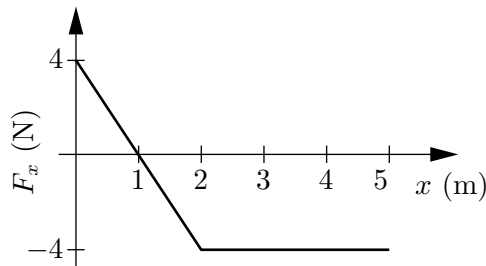
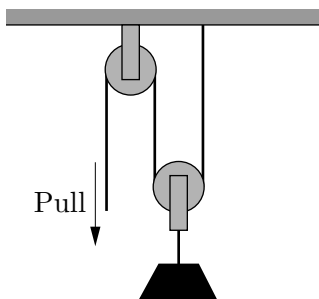


**Problem Set 8**  
(due Wednesday, March 1)

1. Suppose that you throw a rock upward, at an angle, at a speed of 15 m/s. The rock reaches a maximum height of 10 m above the point where you threw it (and an unknown distance horizontally). Use energy conservation to find the speed of the rock at its highest point. Then determine the angle at which you threw the rock.
2. To pull a 50-kg crate across a frictionless floor, a worker applies a force of 210 N, directed 20° above the horizontal. As the crate moves 3.0 m, what work is done on the crate by (a) the worker; (b) the earth (via gravity); (c) the floor (via the normal force)? (d) What is the total work done on the crate by all three forces?
3. The arrangement of pulleys shown below is used for “mechanical advantage” in lifting a heavy object. Suppose that the mass of the hanging object is 20 kg, while the cords and pulleys are massless and frictionless. (a) In order to lift this object at constant speed, what force must you exert on the free end of the cord? (Hint: Draw a force diagram for the hanging mass and the pulley it is connected to, treated together as a single object.) (b) To lift the object by 2.0 cm, how far must you pull the cord? (c) How much work do you perform in pulling the cord this far? (d) How much work is done by the earth (via gravity) on the hanging object during this operation?



4. The graph above shows the only force acting on a 2-kg object moving along the  $x$  axis. The object is initially at  $x = 0$ , with a velocity of  $v_x = 4.0$  m/s. (a) What is the kinetic energy of the object when it reaches  $x = 3.0$  m? (b) At what position will the object have a kinetic energy of 8.0 J? (c) What is the maximum kinetic energy that the object attains over the range of positions shown? (Hint: The work done by the force over any distance equals the area under the graph.)
5. Imagine lifting a 2-kg textbook from a tabletop (height 76 cm above the floor) to a shelf (height 1.54 meters above the floor). (a) How much work must you perform to accomplish this task? (b) How much work is performed by gravity during this process? (c) Calculate the book’s initial and final gravitational energy, taking the floor as your “reference point”, and comment on the results in relation to your answer to part (a). (d) Suppose now that the book slips off the shelf and falls back to the tabletop. How much work is performed by gravity during this process? What is the book’s kinetic energy just before it lands on the tabletop?
6. The space shuttle enters the atmosphere traveling at about 8 km/s, and yet when it lands, its speed has decreased to only about 100 m/s. Where does all the energy go? It must be

converted to thermal energy. Suppose that all this thermal energy were to end up in the shuttle itself. How much thermal energy would each kilogram of the shuttle (and payload) gain during reentry? Please express your answer in kilocalories, and comment on the result.

7. A hiker climbs Mt. Everest (elevation 9000 meters). Under the most ideal circumstances, about how many bowls of cornflakes would she have to eat first? (You'll need to make a few estimates and assumptions here, which you should state clearly in your solution. Use any reasonable value for the hiker's mass, and assume that her efficiency in converting chemical energy to mechanical energy is 25%.)
8. Abel Knaebble (the stunt man) climbs to the top of a tower 65 m tall and dives into a tank of water (initially at body temperature) in the shape of a cube 3 meters on a side. After all the splash and wave energy gets converted to thermal energy, by about how much has the temperature of the water increased? (We're looking for a very rough estimate here; use any reasonable value for Abel's mass.)
9. Measure the time it takes you to climb a flight of stairs, then calculate the rate at which you are converting chemical energy into gravitational potential energy. Express the answer both in watts and in horsepower.
10. Water flows over Niagara Falls at a rate of  $1.2 \times 10^6$  kg/s and falls 50 m. How many 60-watt bulbs can be lit with this power?

## Study Guide

(Work done by  $\vec{F}$ ) =  $|\vec{F}||\Delta\vec{r}|\cos\theta = \vec{F} \cdot \Delta\vec{r}$ . If  $\vec{F}$  or the direction of travel varies, we must break up path into tiny steps and add up all the little works to get the total work. For one-dimensional motion, this implies that work is the area under a graph of force vs. position.

Work-energy relation: The net work done on a particle by all forces acting on it equals the change in its kinetic energy.  $\sum W = K_{\text{final}} - K_{\text{initial}}$ . (A "particle" is any object whose internal structure is irrelevant to the situation at hand. The concept of work is ambiguous for an object whose shape can change.) If some of the forces have associated potential energy functions, then the work done by all *other* forces equals the change in the *total* energy (including potential energy).

Besides kinetic, gravitational, and spring energy, other forms of energy include chemical (as released by burning fuels), nuclear, thermal (usually manifested by an increase in temperature), other types of potential energy (such as electrostatic), and energy carried by sound waves and electromagnetic waves. Some of these categories overlap; for instance, thermal energy is partly due to kinetic energies of individual molecules jostling about.

For any isolated system of objects (possibly interacting with each other but not subject to outside forces), the total energy is conserved:  $\sum E_f = \sum E_i$ . Here each sum includes all types of energy for all objects in the "system". This is the most general form of the law of conservation of energy, and is not subject to all the restrictions that apply to conservation of mechanical (i.e., kinetic plus potential) energy.

1 calorie = (energy to raise the temperature of a gram of water by 1 °C) = 4.186 J. The familiar food calorie (sometimes spelled with a capital C) is actually a kilocalorie, 4186 J.

Power = (energy converted)/(time required), that is, the rate at which energy is converted from one form to another. Power is measured in J/s, or watts. So a joule is a watt-second. A watt-*hour* is 3600 watt-seconds, and a *kilowatt-hour* is 1000 watt-hours.